ANNUAL REPORT
HABITAT ASSESSMENT FUNDED RESEARCH

Project Title:

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Prioritizing spawning habitats in terms of their relative contribution to recruitment success 2____

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Goals:

- Develop two new modules for the Connectivity Modeling System (CMS), to improve predictions from existing and future models
- Estimate survival rates for red snapper eggs spawned from natural vs. artificial habitats
- Identify likely spawning areas for gag in the Gulf of Mexico

Approach:

The project initiated by hiring a computer programmer to develop new modules for the Connectivity Modeling System (Paris et al. 2013). Two modules were originally proposed: 1) a spatially-explicit mortality term that will allow mortality rates of larvae to differ in both space and time, and 2) the ability to adjust the vertical distributions of larvae based on depth at the larvae's location. These modifications will allow us to more accurately model the biology of the larvae based on existing data, such as sampling of vertical distributions carried out on the shelf versus open ocean or knowledge of larval mortality in relation to temperature, chlorophyll, or other spatially-explicit drivers. Once these modifications are complete, and the code has been fully tested and debugged, a number of simulations will be carried out with respect to research questions on red snapper and gag grouper in the Gulf of Mexico.

Work Completed:

For the HAIP project, modeling efforts with CMS are focused on refining the CMS capabilities to represent crucial processes taking place during early larval stages. By enhancing the CMS's ability to represent important larval traits, we are also improving the estimations of recruitment contribution relative to oceanographic factors which are used for stock assessment and conservation measures.

To date, three new modules were implemented on CMS: i) onset of competency period regulated by water temperature, ii) spatially-explicit mortality scheme defined by temperature, and iii) distinct ontogenetic vertical migration schemes based on the depth at the larvae's location. These three modules are described below.

Initial tests with these modules were conducted by dispersing larvae in the Florida Keys region for 3 months. The next step in the project is to conduct further testing of the module, including dispersal in the key region of the northern Gulf of Mexico. Furthermore, we expand the newly created modules, allowing more flexibility and user customization. Specifically, we aim to: i) create a mortality module responding not only to temperature, but also to other environmental factors, such as chlorophyll; ii) create other conditions for how temperature affects the onset of larval settlement (maximum temperature experienced by larvae, temperatures above or below a threshold) and iii) vertical migration driven by environmental factors, such as salinity (Paris and Cowen, 2004).

Description of new CMS modules

Mortality and onset of settlement defined by temperature

Motivation: Temperature can both directly and indirectly influence both larval growth and mortality rates. This influence is primarily related to individual metabolism, but community processes, such as ecosystem productivity, also play an important role. Given the overwhelming evidence of temperature affecting growth and mortality rates of planktonic organisms (Houde 1989, O'Connor et al. 2007), it is essential to include this influence on the simulation of larval growth and dispersal.

The new module developed on CMS can use water temperature to mediate the start of the larval competency period. When larvae reach the minimum age for settlement (user defined based on values from the literature), CMS will calculate a new onset for the competency period, based on the averaged temperature experienced by the larvae. The onset of settlement for each larva is calculated using the relationship given by Houde (1989):

$$D = 952.5T^{-1.0752}$$

Where D is the larval stage duration in days and T is the water temperature in degrees Celsius.

When using this module, the user must still define the minimum age a larva can reach their competency period. This information is available for a wide range of species, and will be used as the baseline for the calculation of the temperature regulated onset of settlement. For any given larva, if the age of settlement calculated by the temperature is smaller than the minimum settlement age provided by the user, the larva will be set as dead and removed from the simulation. If it is bigger, settlement will start on the day defined by the temperature regulated settlement start.

A new mortality module was also developed for CMS, allowing the mortality rate to be defined explicitly in both time and space. In this initial format, CMS can use water temperature to control mortality rates. When using this module, an instantaneous mortality rate for each larva will be calculated based on the water temperature they are experiencing.
The mortality rate follows Houde (1989), and was based on observations of early life stages organisms:

$$Z = 0.0256 + 0.0123\ T$$

Where z is the daily mortality rate and T is the water temperature in degrees Celsius.

Vertical migration varying with depth

Motivation: Vertical migration of larvae is partially controlled by environmental factors, such as salinity, temperature, and light availability. The depth of the water column can directly influence the extent of the vertical migration, for instance, larvae of species dispersing over both shallower continental shelves and deep oceanic areas can present significantly different vertical migration behavior. Therefore, it is fundamental to consider these differences when modeling vertical migration.

The option **ibioShallow** allows for the user to use two different migration matrices: one for deeper oceanic areas (ibio) and another for shallower regions (**ibioShallow**). If using this option, you must provide a second matrix of vertical migration probabilities, which must be configured following the same description of ibio. You also need to provide the depth of water column when CMS will transition from using ibioShallow to use ibio.

In addition to the programming work, a post-doctoral scientist was trained in the use of the CMS. The post-doc will assist in carrying out new simulations, writing up results, and communicating the applications of the project to the appropriate management audiences.

References:

Houde E. D. Comparative growth, mortality and energetics of marine fish larvae: temperature and implied latitudinal effects. Fishery Bulletin 887:471-495.

O'Connor M. I., Bruno J. F, Gaines S. D., Halpern B. S., Lester S. E., Kinlan B. P. and J. M. Weiss. 2007. Temperature control of larval dispersal and the implications for marine ecology, evolution and conservation. Proceedings of the National Academy of Sciences 104:1266-1271.

Paris C. B. and R. K. Cowen. 2004. Direct evidence of a biophysical retention mechanism for coral reef fish larvae. Limnology and Oceanography 49:1964-1979.

Paris C. B., J. Helgers, E. Von Sebille and A. Srinivasan. 2013. Connectivity Modeling System: a probabilistic modeling tool for the multi-scale tracking of biotic and abiotic variability in the ocean. Environmental Modelling and Software 42:47-54.

Applications:

Programming of the new modules is complete, but there are still some testing and debugging steps to be carried out before the new code is released. Once this occurs, the project will move into the application stage, to carry out simulations which will provide management advice on red snapper and gag grouper in the Gulf of Mexico.

Publications/Presentations/Webpages:

Updates to the code are continually made on the Google Code webpage:

https://code.google.com/p/connectivity-modeling-system/

Please attach visuals for Habitat Science Webpage (pictures, maps, charts from project)

These are in progress and will be made available in the final report.